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NUCLEAR RADIATION EFFECTS ON INFRARED MATERIALS AND COMPONENTS, PART I

EFFECTS OF GAMMA RADIATION ON INFRARED TRANSMITTING MATERIALS AND FILTERS

AUTHORS: CLYDE C. SHAW
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SOLID STATE ELECTRONICS DEPT.

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## EFFECTS OF GAMMA RADIATION ON INFRARED TRANSMITTING MATERIALS AND FILTERS

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Division: Electronics
Branch: R&D Branch


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Summary of Report

Results of a survey of cobalt-60 gamma radiation effects on the optical properties of a number of infrared transmitting materials and filters are presented.

This study shows that, with few exceptions, the materials and filters are insensitive to gamma radiation at a dosage level of $10^7$ roentgens or more.


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# NUCLEAR RADIATION EFFECTS ON INFRARED MATERIALS AND COMPONENTS, PART I

## EFFECTS OF GAMMA RADIATION ON INFRARED TRANSMITTING MATERIALS AND FILTERS

### Introduction

The infrared systems designer is confronted with a number of problems arising from interactions of the system with the environment in which his device is required to operate. An increasingly important addition to the catalog of environmental effects is that due to nuclear radiation. The importance of considering the effects of this environment becomes apparent whenever the system must be designed to operate in the vicinity of a source of nuclear radiation, such as a nuclear power source.

It was with the purpose in mind of providing the information useful to the infrared systems designer that a study of nuclear radiation effects on infrared materials and components was initiated at the Lockheed Missile Systems Division Research Laboratories.

It is proposed that the results of this investigation be presented in a series of reports, of which this is the first. These reports will include gamma-ray and neutron radiation damage to infrared transmitting

materials, filters, and detectors. As new and interesting materials and components become available they will be evaluated and the results included in periodic supplementary reports.

This first report will be confined to a study of the effects of gamma radiation on the infrared transmission of optical materials and infrared filters. It is presented as a survey of a number of useful infrared materials, rather than as a scientific study or a tutorial article. For information of this character, the reader is referred to a recent publication by G. J. Diener and G. H. Vineyard, Radiation Effects in Solids, Interscience Publishers, Inc., New York, 1957, and the included bibliography.

## Experimental Procedure

Infrared transmission curves of the optical materials and filters were obtained before and after exposure to radiation. In this study a double-pass, single-beam Perkin-Elmer Model #112 Universal Infrared Spectrometer was used. This instrument employed a globar source, a rock-salt prism, and a thermocouple detector with a KBr window. The experimental error in determining transmittance as a function of wavelength was found to be less than 4%.

The samples were irradiated by exposure to cobalt-60 gamma radiation in the Lockheed Missile Systems Division 100 curie facility. Dosimetry measurements on this source show that a maximum dose rate of 2 X $10^5$ roentgens/hr can be obtained for small samples. However, in this study a

dose rate of $10^5$ roentgens/hr was used. Irradiations and spectral transmission measurements were all conducted at room temperature.

In addition to the gamma irradiation studies, an available polonium-beryllium source was used in a low-flux neutron irradiation investigation of the optical materials. A neutron flux of $10^5/cm^2$ sec. was obtained from this source.

Results

Selection of infrared optical materials to be tested in this study was based on a number of factors. Consideration was given to all materials with optically useful transmittances in some region of the infrared spectrum above 2 microns; however, the very hygroscopic and the more chemically, or thermally, unstable substances were ruled out.

The accompanying transmission curves show the percent transmission as a function of wavelength for the materials tested. The infrared transmittances of most of the substances examined were, for all practical purposes, unaffected by a total accumulated gamma dosage of $2 \times 10^7$ roentgens. In the interest of completeness, the curves of all materials examined, including those not affected by radiation, are shown.

The following infrared materials were studied:

1) 7905 Vycor: This product of Corning Glass Works avoids the strong absorption band at 2.7 microns that is a characteristic of most silica glasses. A gamma dose of $2 \times 10^7$ roentgens rendered it opaque in the visible region of the spectrum, but produced only a very slight

depression in its infrared transmittance. The radiation induced transmission properties of this material, shown to be relatively stable below about 250° C, may have possible applications as band-pass filters in the near infrared region.

2) Quartz: A number of samples of commercially available quartz (Amersil, General Electric, etc.) were surveyed. The post-irradiation transmission curves showed the same opacity in the visible region as did the Vycor.

3) Fused Silica: This material, recently developed by Corning Glass Works and claimed to be 100% pure $SiO_2$, was exposed to a total gamma dosage of $10^8$ roentgens with no observable effects in its infrared transmission properties. It has been suggested that this unique resistance to radiation damage results from the absence of impurities normally found in quartz and glass.

4) Calcium Aluminate Glass: A number of types of calcium aluminate (RIR-10, 11, 12, 2, 20), supplied by Bausch & Lomb Optical Company were studied. All samples were, within the experimental error, found to be unaffected by gamma dosages of $10^7$ roentgens. A typical transmission curve is shown.

5) Arsenic Trisulfide Glass: Samples of this material, available from the Servo Corporation of America under the trade name "Servofrax", showed no change in optical properties after a 2 X $10^7$ roentgen gamma dose.

6) Selenium Glass: Eastman Kodak Company has recently developed an arsenic-selenium glass with an index of refraction of 2.45 or higher, and a transmittance that is optically useful out to 25 microns.

The accompanying curve shows its transmittance, which showed no change after $10^7$ roentgens, out to the long-wavelength limit of the spectrometer.

7) Magnesium Oxide: Samples of MgO (periclase) were obtained from two sources. High-purity optical quality crystals supplied by the Infra-Red Development Company, England, appeared completely resistant to gamma radiation at a dosage level of $2 \times 10^7$ roentgens. However, this dosage induced an absorption band near 2.5 microns in commercial grade magnesium oxide obtained from Norton Company.

8) Sapphire: Thin windows of $Al_2O_3$ supplied by Linde Air Products Company were exposed to a gamma dosage of $2 \times 10^7$ roentgens with no observable optical effects.

9) Silicon: The infrared transmission of high-purity, single-crystal windows of Texas Instruments, Incorporated silicon remained unchanged after $2 \times 10^7$ roentgens.

A representative number of various types of infrared filters were evaluated with respect to gamma radiation effects.

The spectral transmittance of each filter was obtained before and after exposure to an accumulated gamma dosage of $10^7$ roentgens. Within limits of experimental error, the infrared transmission properties of all samples tested remained unchanged, both with respect to radiation-induced infrared absorption bands and detuning effects. Again, infrared transmission curves have been included which plot percent transmission as a function of wavelength in microns.

Two types of filters were examined. These included Bausch & Lomb interference filters, and glass absorption filters from Corning Glass. The first type may be obtained either as band-pass filters or as long-wavelength-pass filters. Proper combinations of the two types result in composite filters with clean, single-band transmission characteristics.

Also shown in this report are the transmission curves of two multiple-layer interference filters developed by R. G. Greenler(1) of Johns Hopkins University.

With reference to the results of the previously mentioned low-flux neutron irradiation study, it came as no surprise that integrated fluxes of $2 \times 10^{10}$ $cm^{-2}$ produced no observable effects. This phase of the investigation will be extended to include high-flux neutron irradiations.

(1) Greenler, R. G., J. Opt. Soc. 45, 788(1955); 47, 130(1957)

## Conclusions

The results of this study show that, with few exceptions, infrared optical materials and filters are insensitive to gamma radiation at a dosage level of $10^7$ roentgens or more. In those cases where the optical properties are affected, the changes are not necessarily detrimental to the operation of infrared systems employing these particular materials.

A note of caution with regard to the behavior of some of these materials, in particular substances containing silica, appears to be in order. A study[2] conducted at the Boeing Airplane Company has indicated the existence of luminous emanation from a number of optical materials under gamma bombardment. It is proposed that this effect will be investigated as part of the general nuclear radiation study at a future date.

(2) Barton, J. A. and Steele, H.L., Boeing Rep. D2-1662 (Jan. 11, 1957)

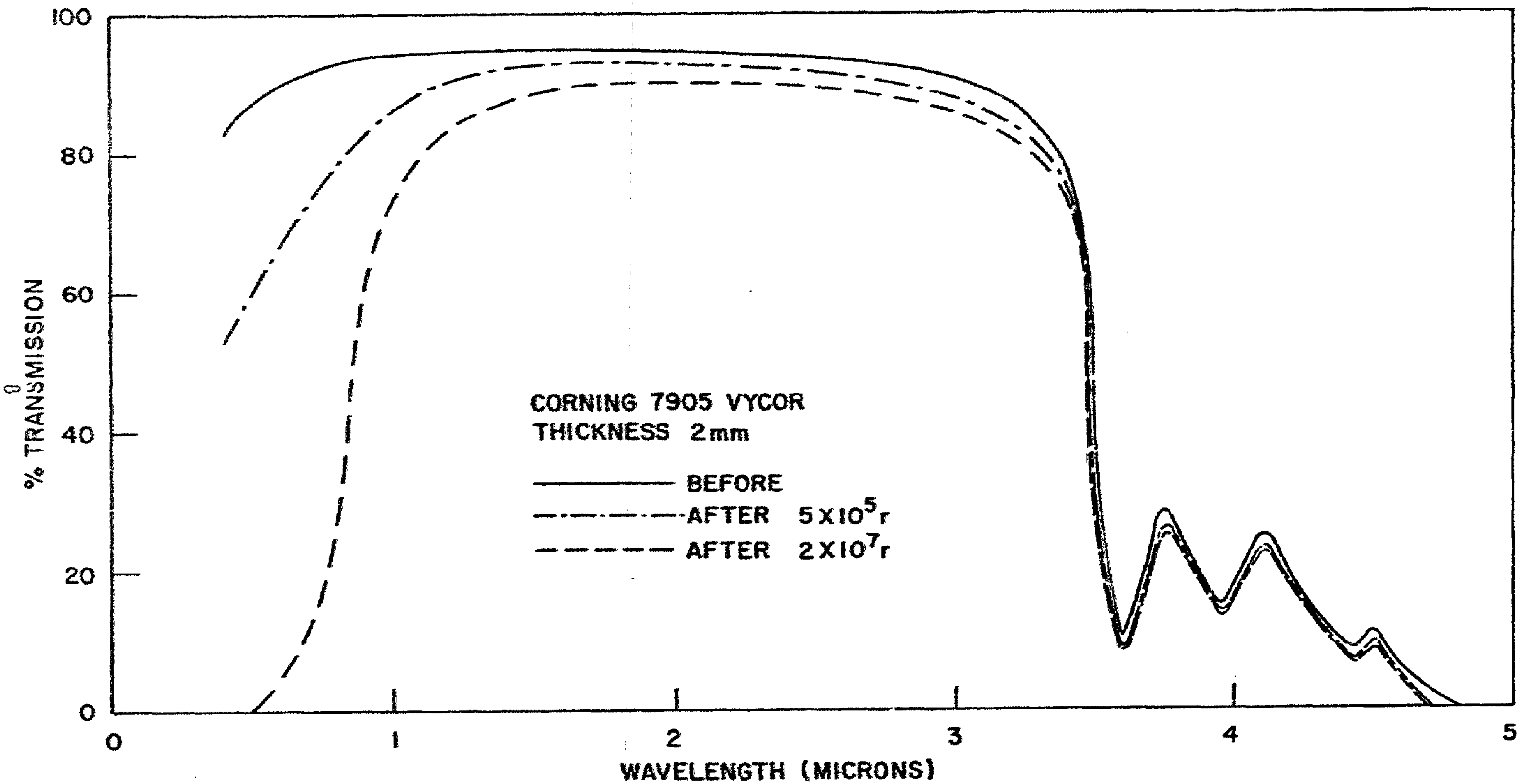


Fig. 1 Optical Transmission Spectrum of Corning 7905 Vycor

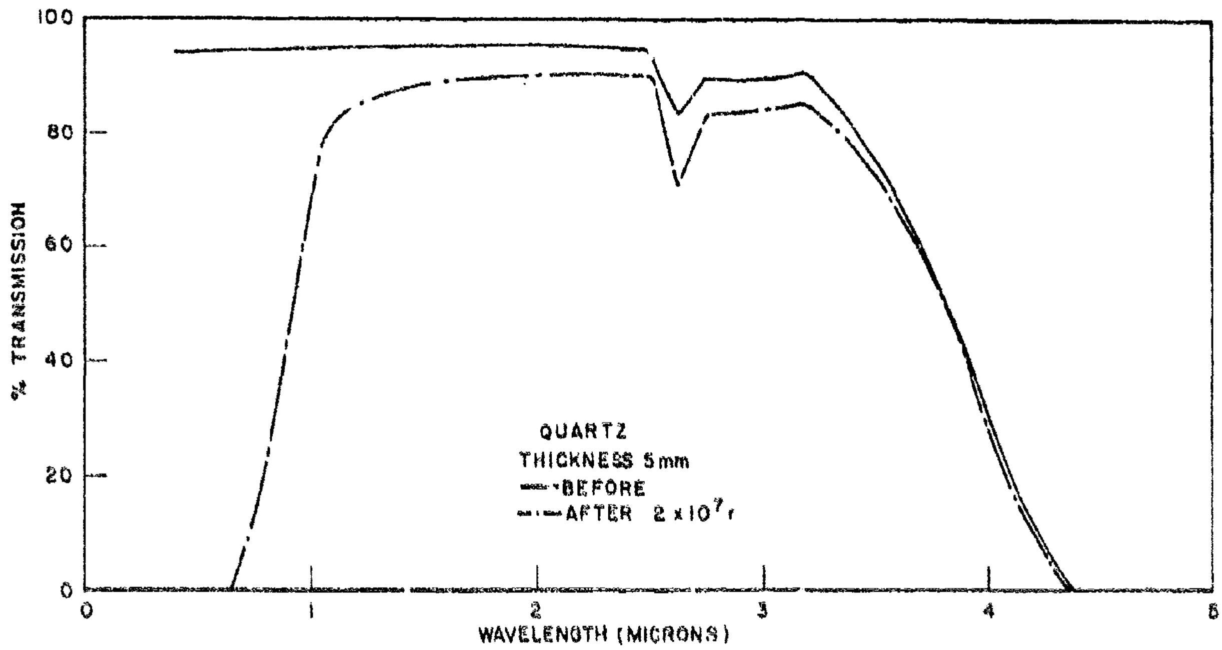


Fig. 2 Optical Transmission Spectrum of Quartz

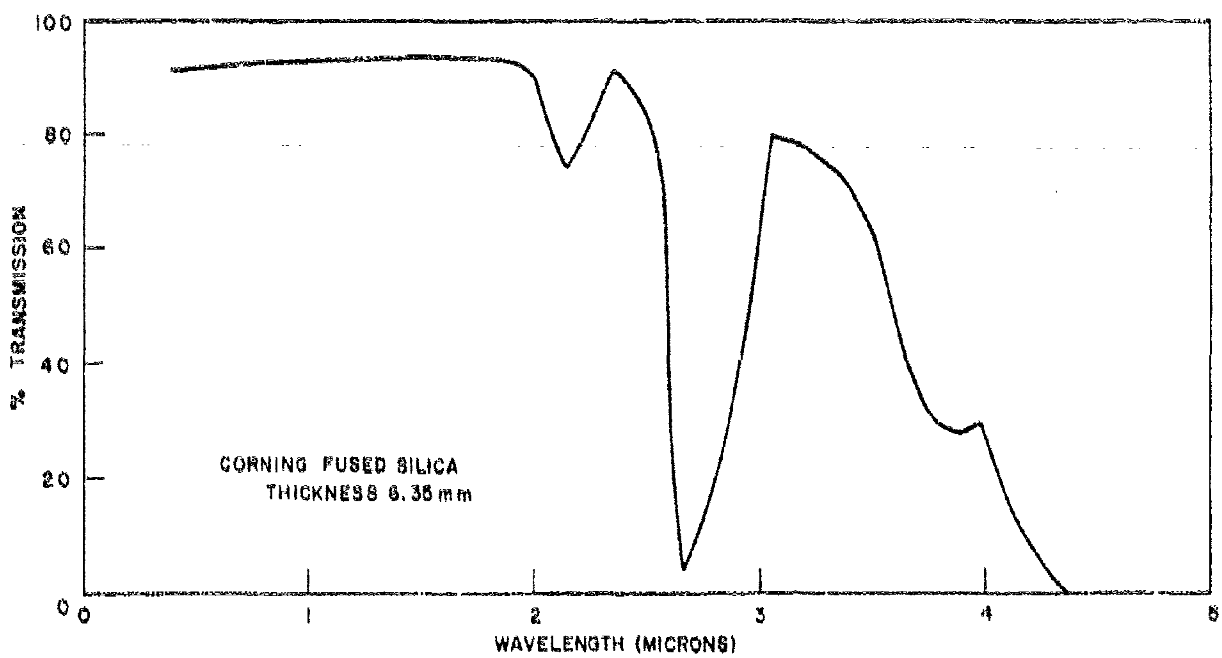


Fig. 3 Optical Transmission Spectrum of Corning Fused Silica

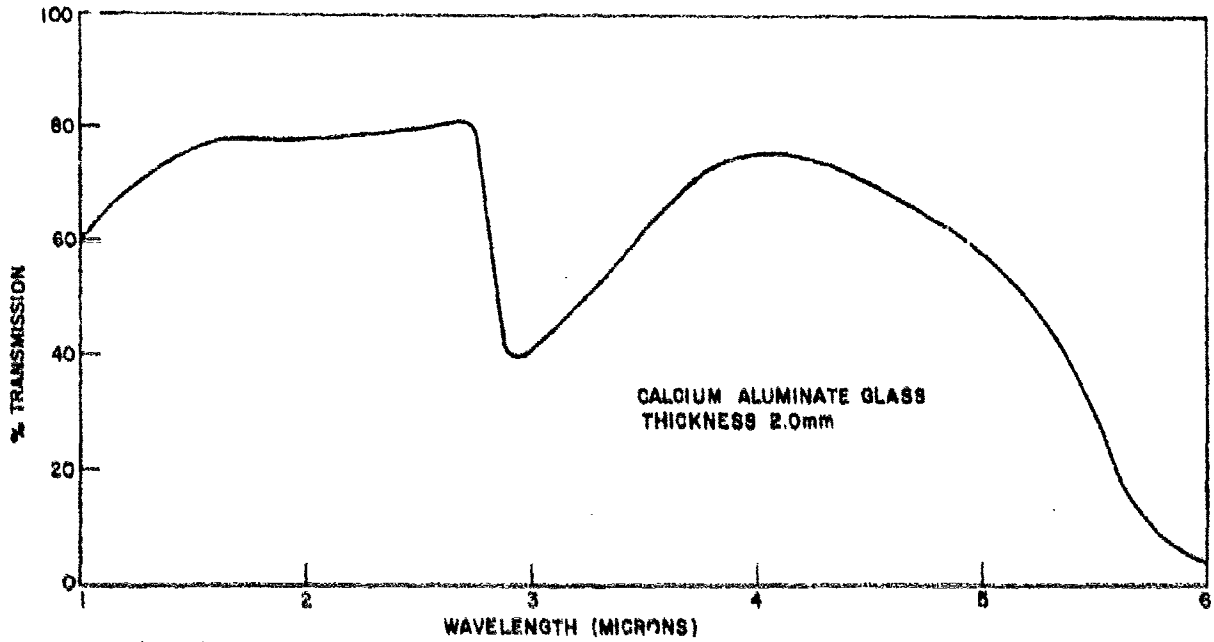


Fig. 4 Optical Transmission Spectrum of Calcium Aluminate Glass

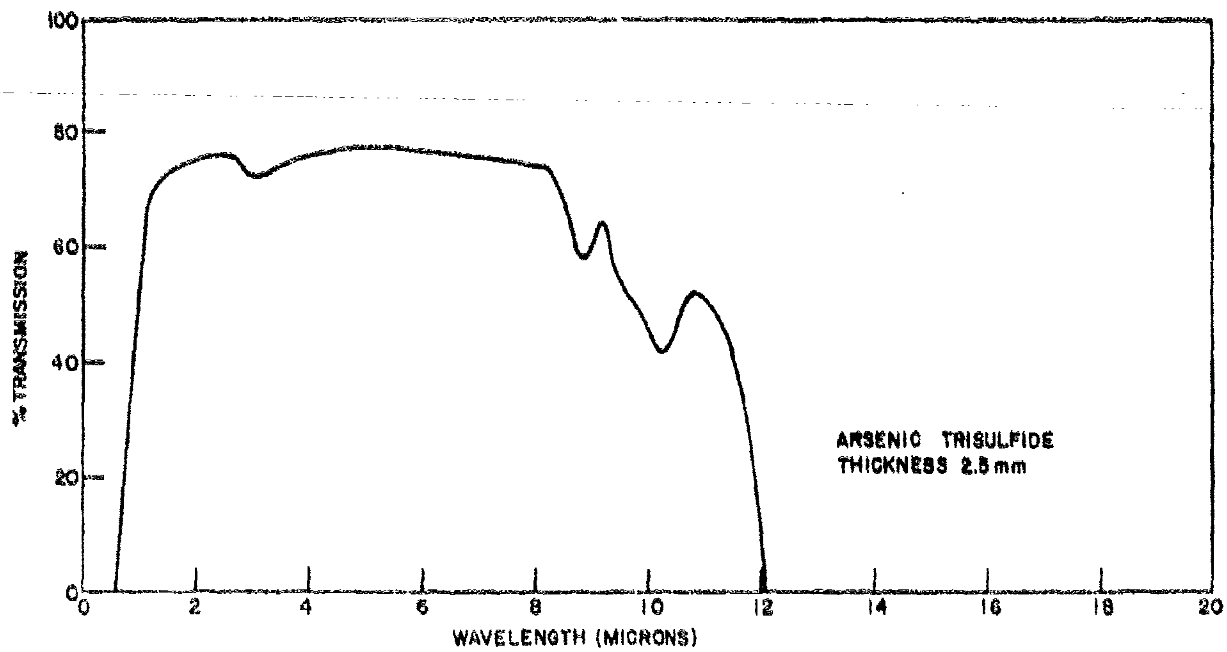


Fig. 5 Optical Transmission Spectrum of Arsenic Trisulfide

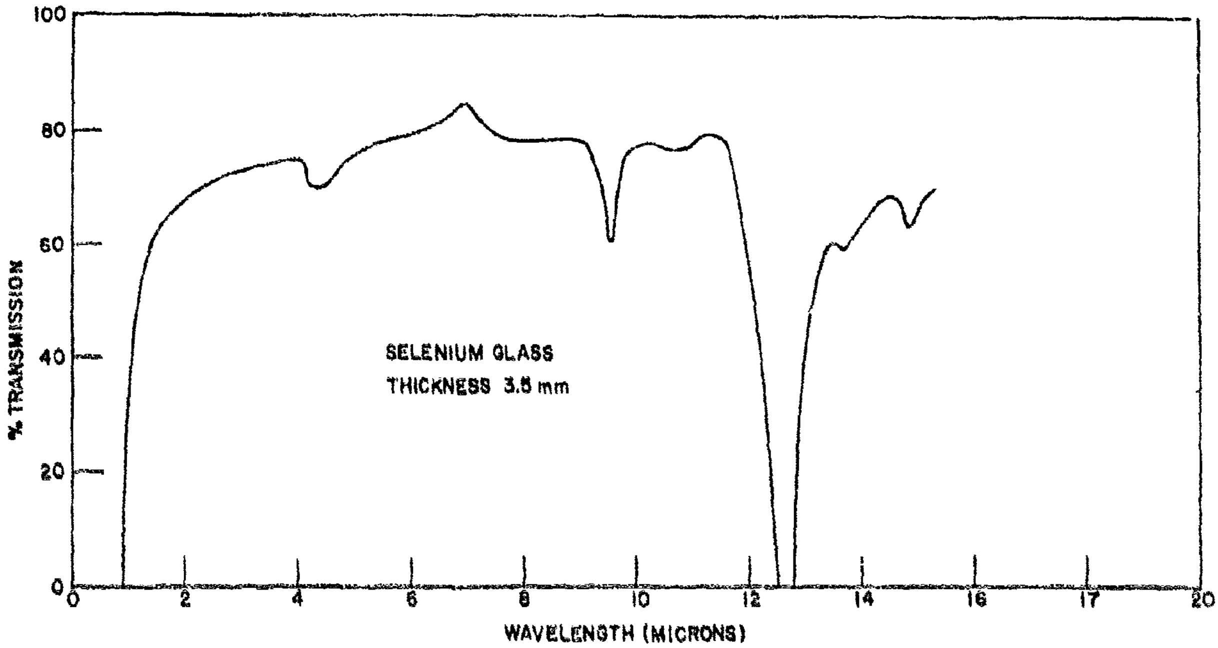


Fig. 6 Optical Transmission Spectrum of Selenium Glass

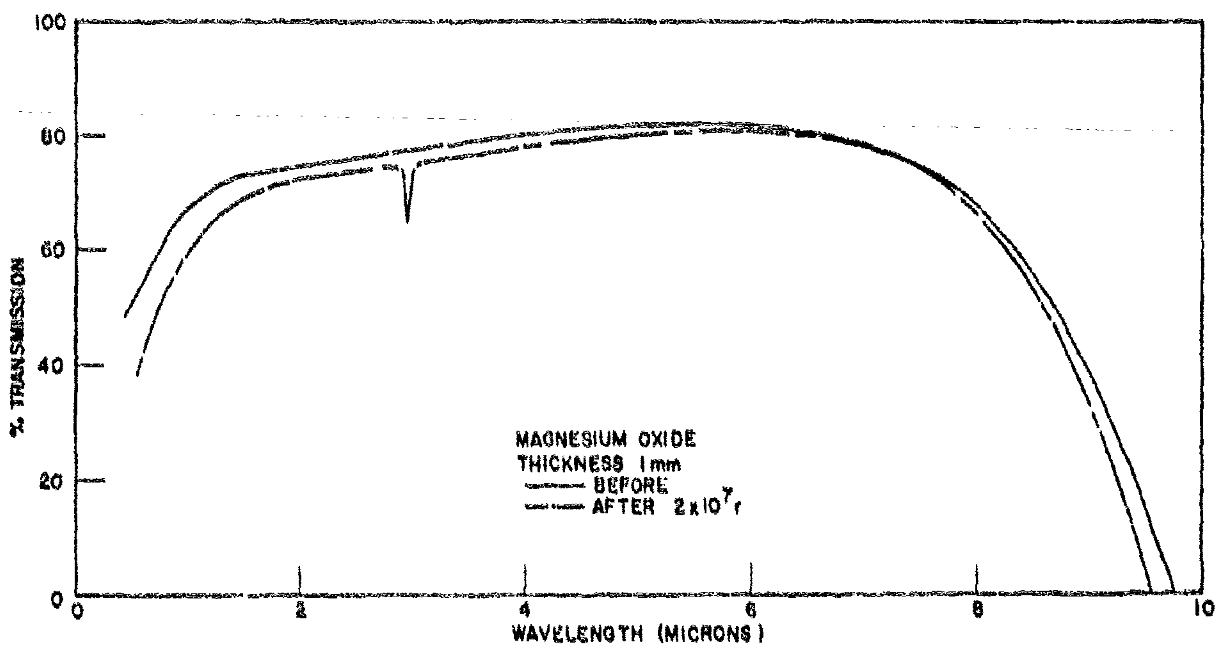


Fig. 7 Optical Transmission Spectrum of Magnesium Oxide

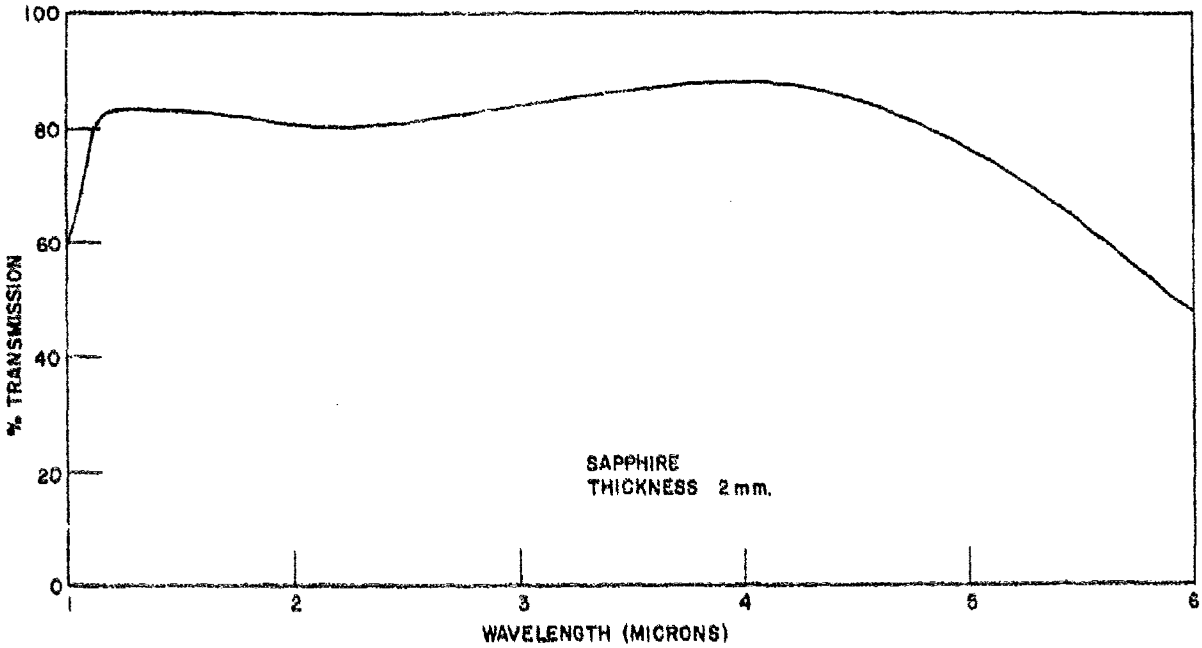


Fig. 8 Optical Transmission Spectrum of Sapphire

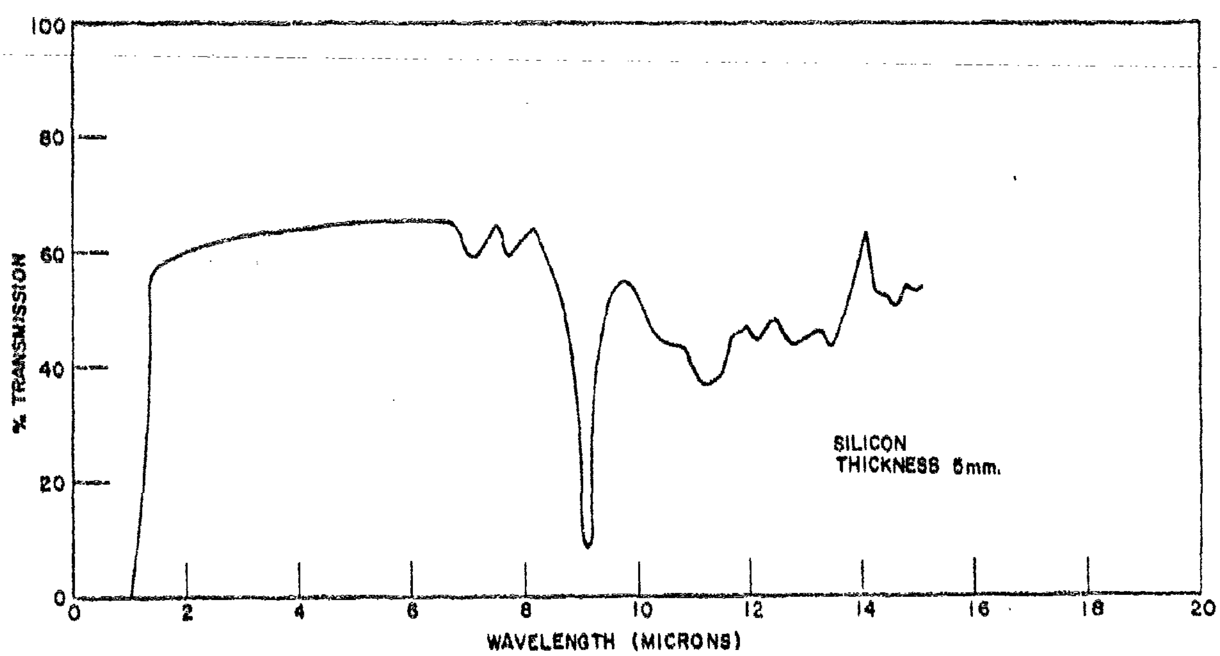


Fig. 9 Optical Transmission Spectrum of Silicon

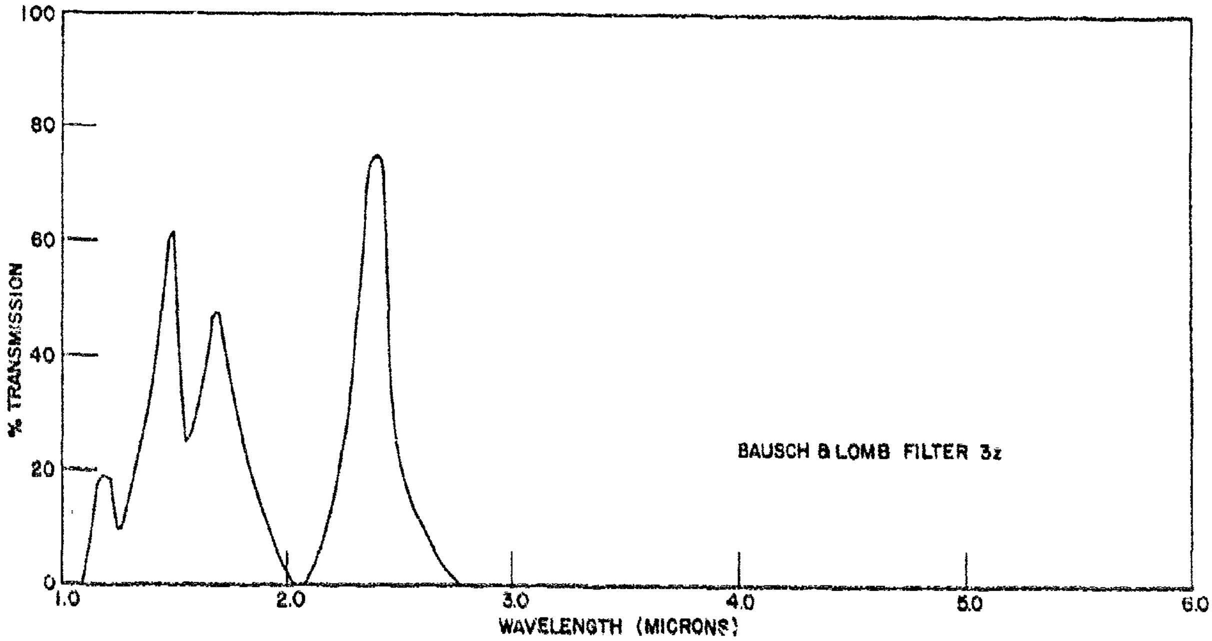


Fig. 10 Optical Transmission Spectrum of Bausch & Lomb Filter $3_z$

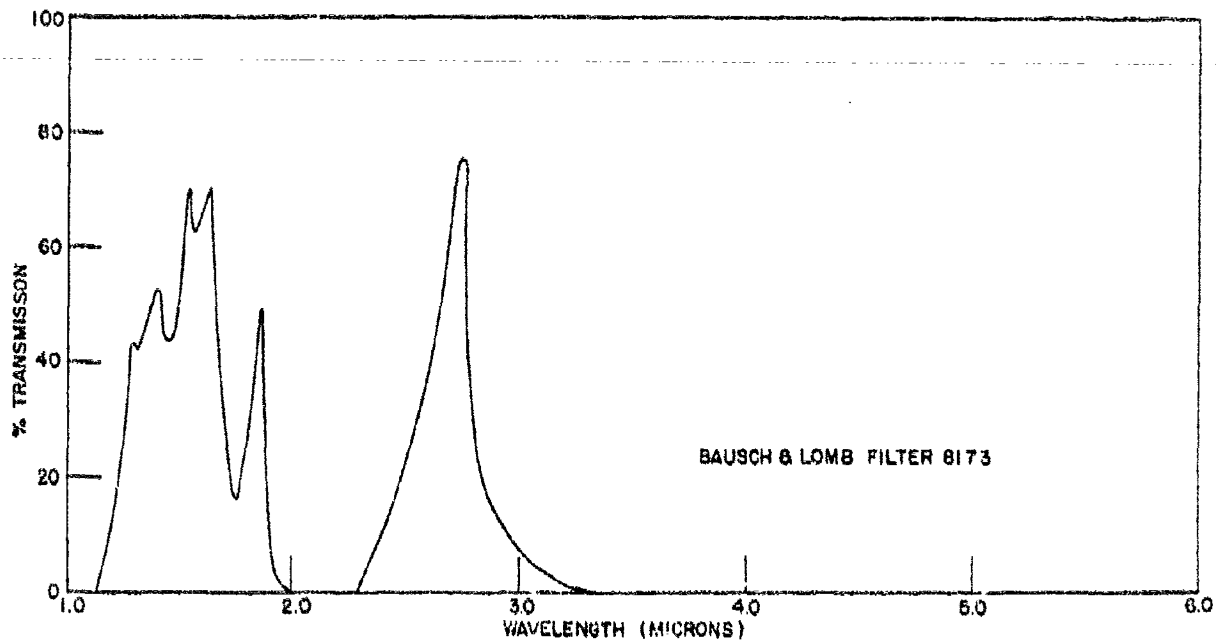


Fig. 11 Optical Transmission Spectrum of Bausch & Lomb Filter 8173

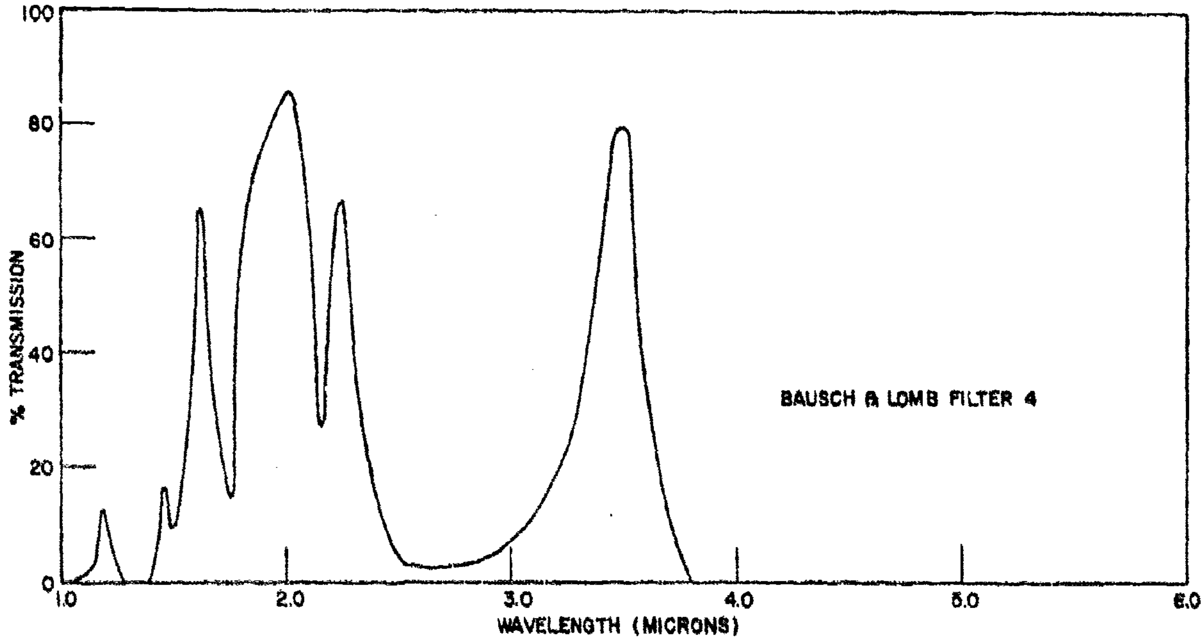


Fig. 12 Optical Transmission Spectrum of Bausch & Lomb Filter 4

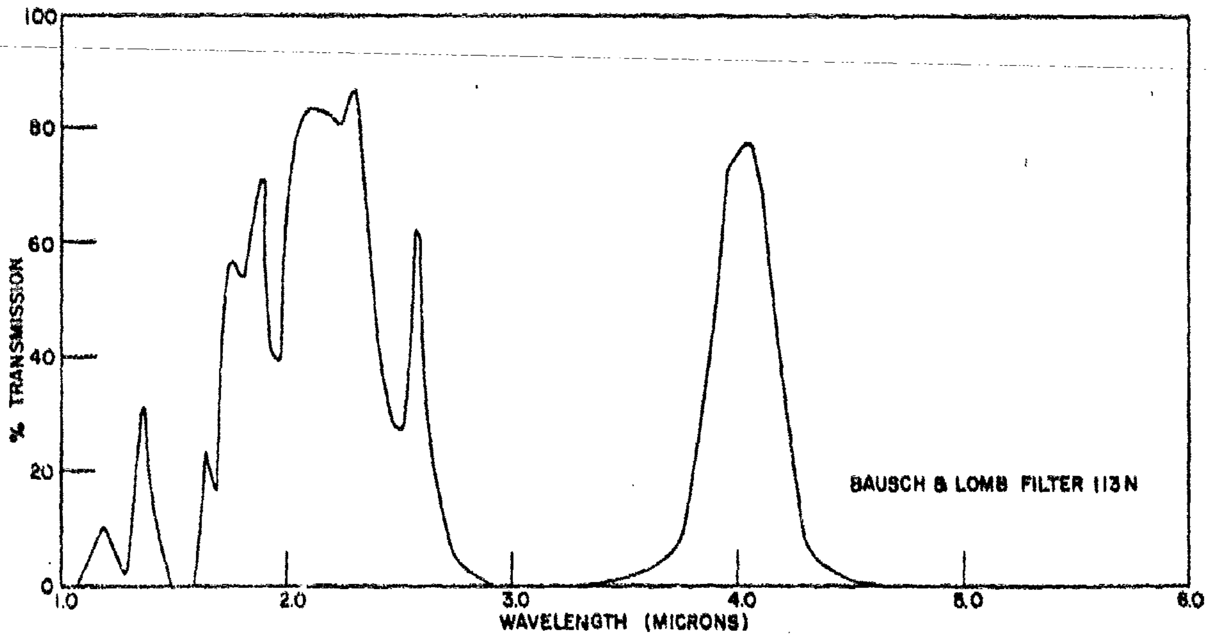


Fig. 13 Optical Transmission Spectrum of Bausch & Lomb Filter 113N

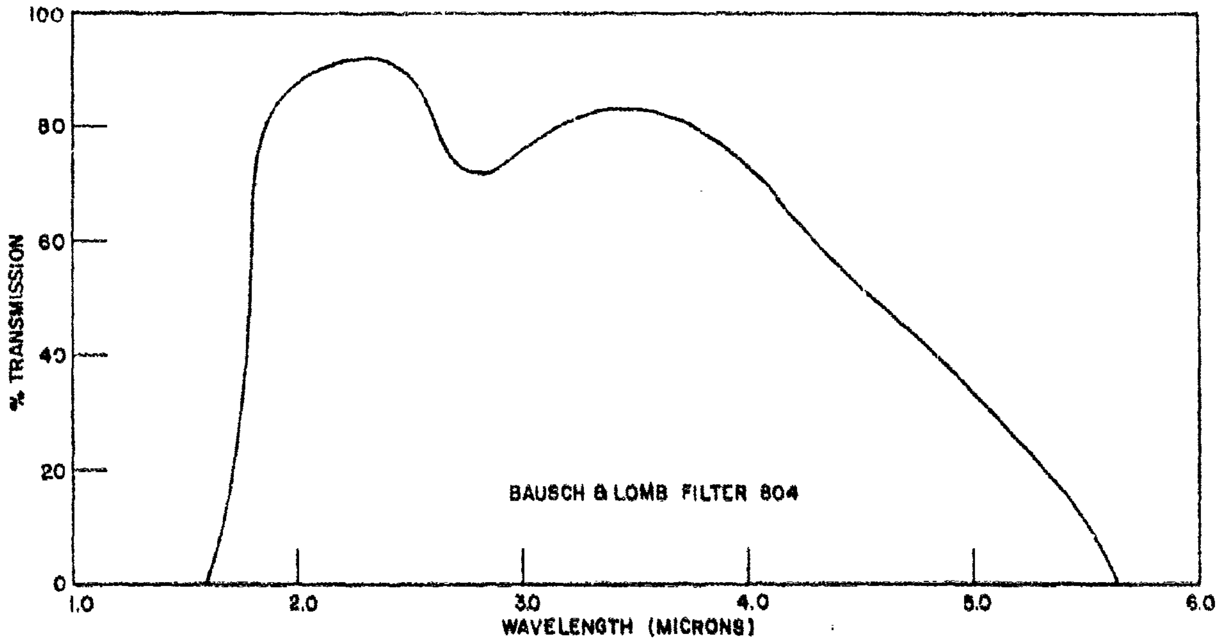


Fig. 14 Optical Transmission Spectrum of Bausch & Lomb Filter 804

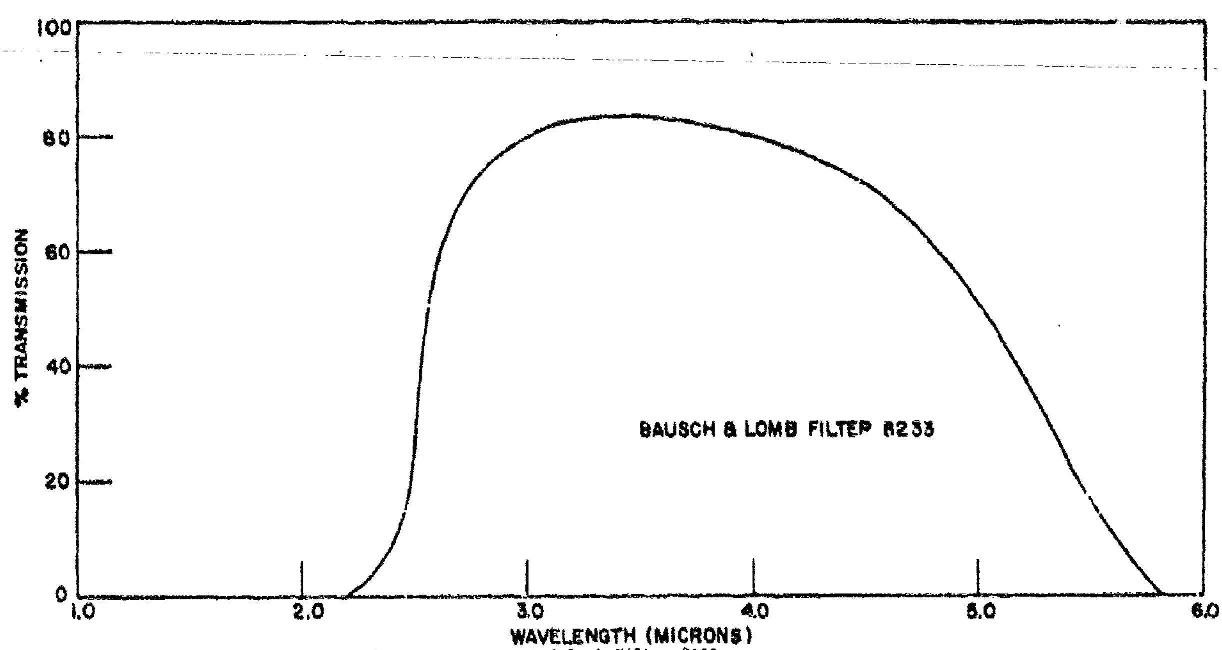


Fig. 15 Optical Transmission Spectrum of Bausch & Lomb Filter 8233

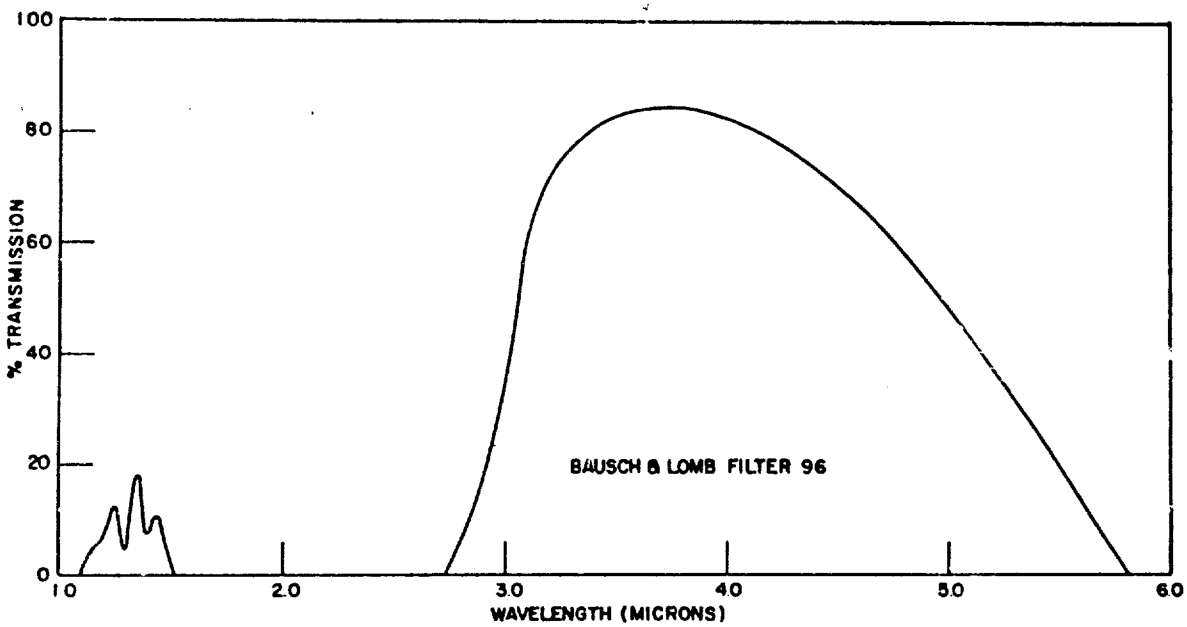


Fig. 16 Optical Transmission Spectrum of Bausch & Lomb Filter 96

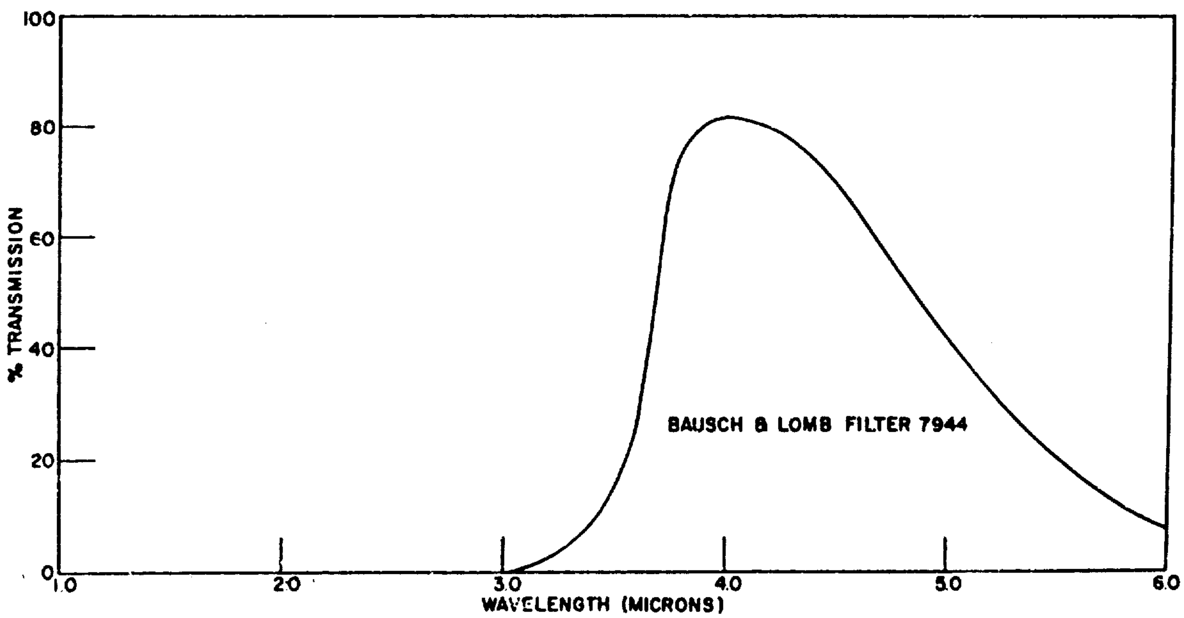


Fig. 17 Optical Transmission Spectrum of Bausch & Lomb Filter 7944

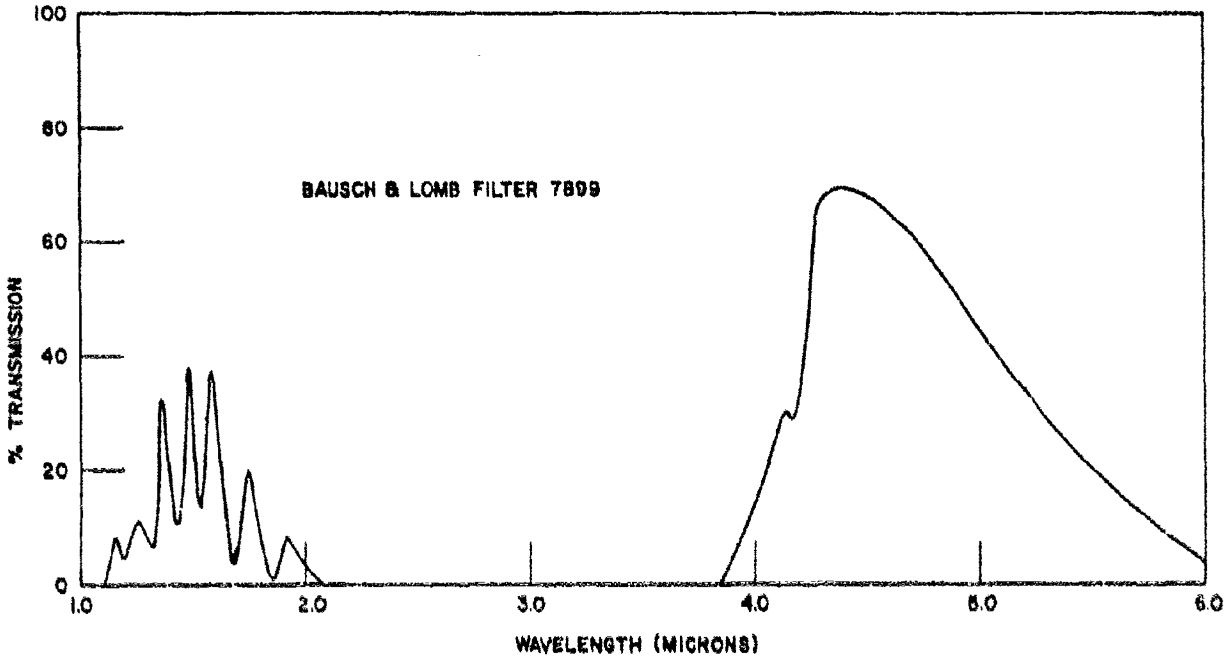


Fig. 18 Optical Transmission Spectrum of Bausch & Lomb Filter 7899

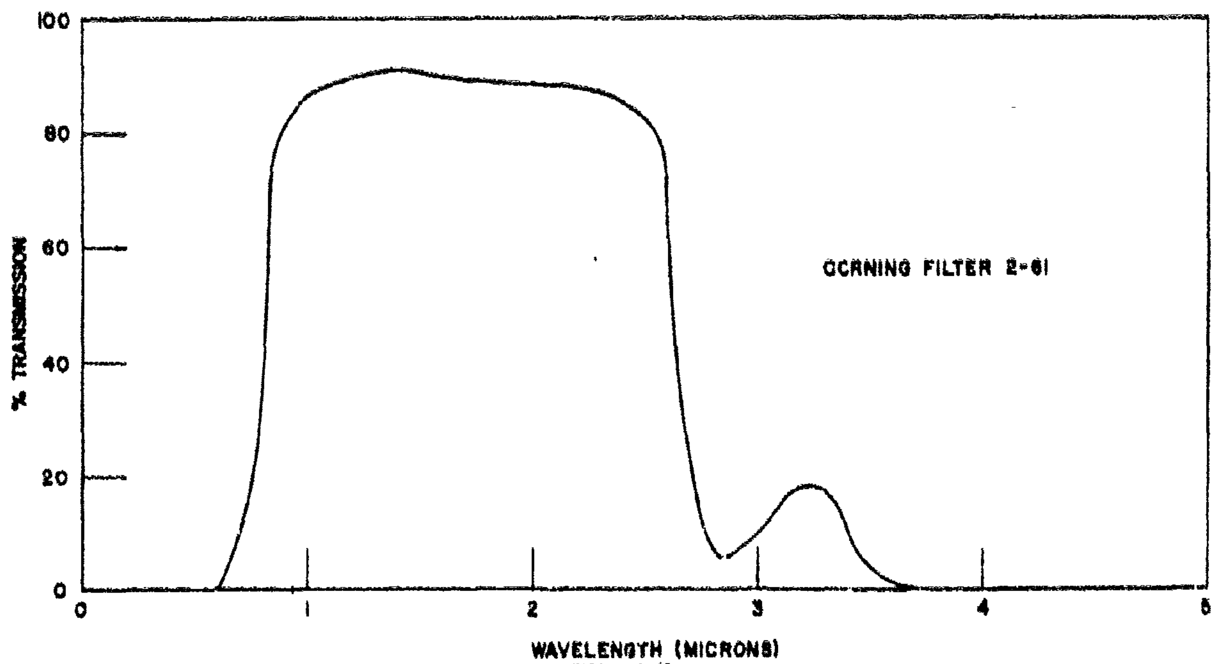


Fig. 19 Optical Transmission Spectrum of Corning Filter 2-61

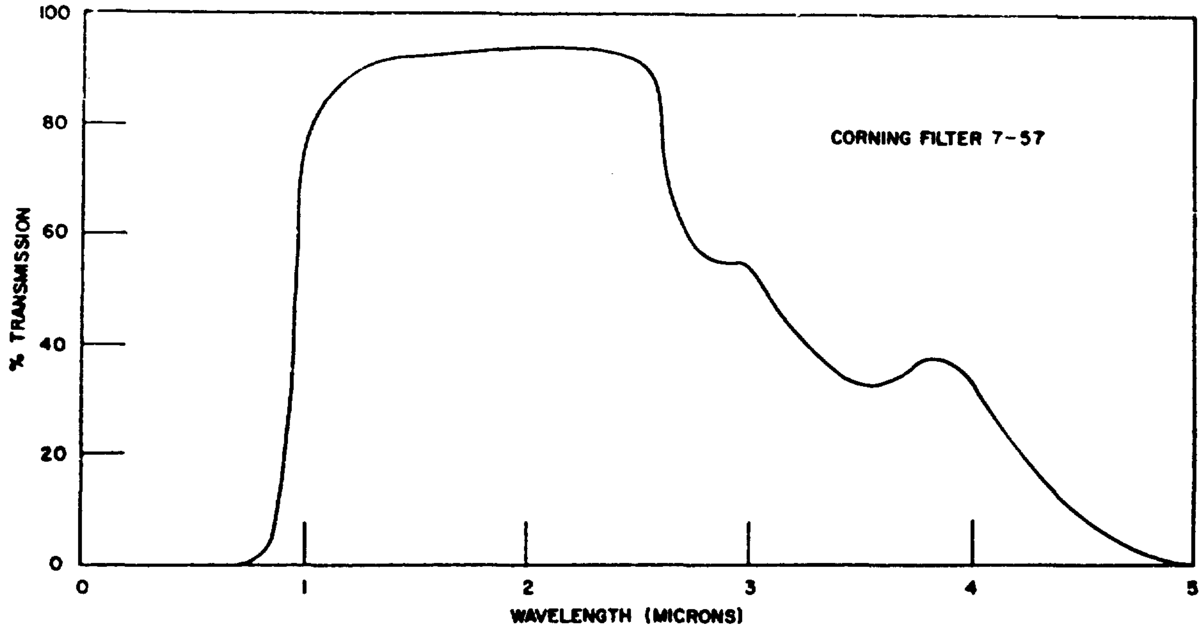


Fig. 20 Optical Transmission Spectrum of Corning Filter 7-57

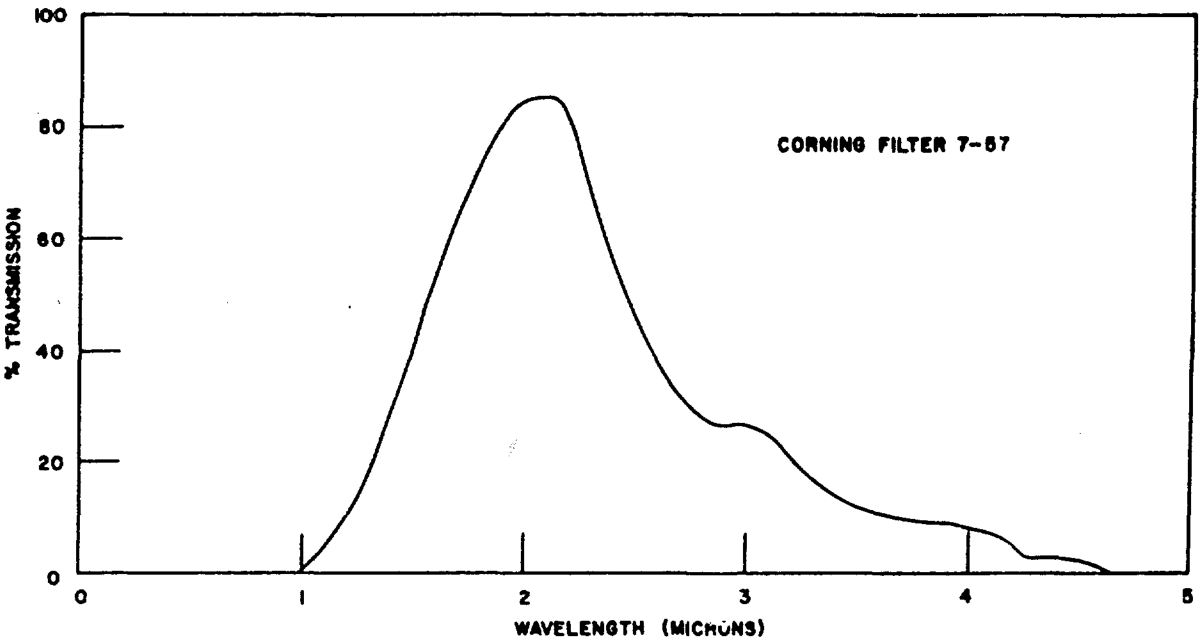


Fig. 21 Optical Transmission Spectrum of Corning Filter 7-57

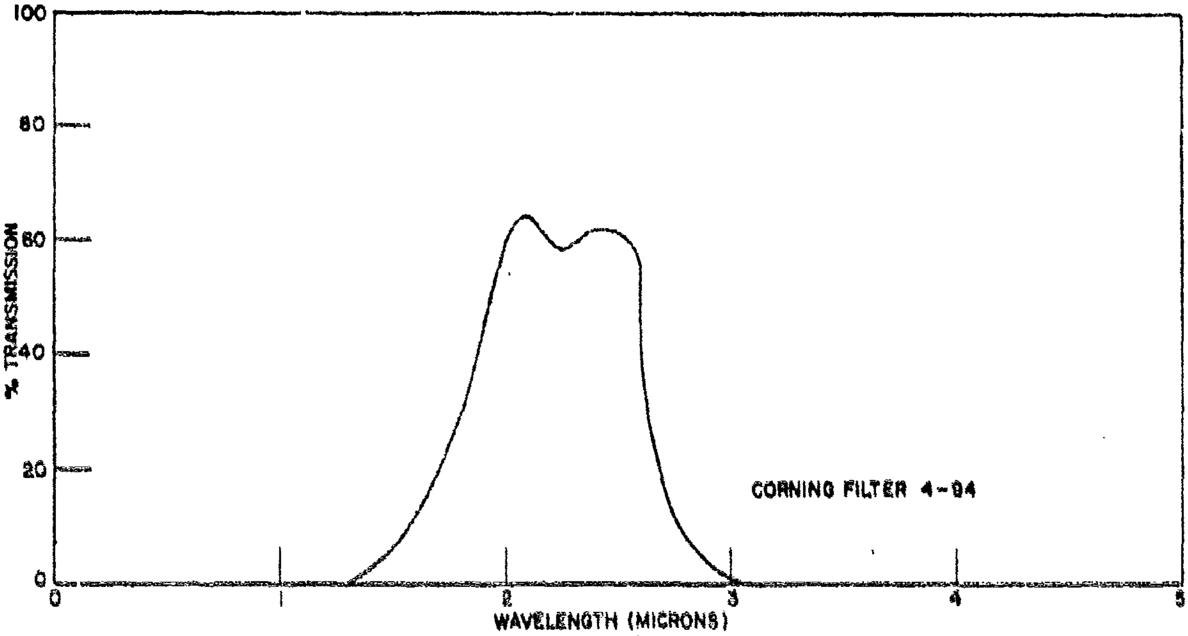


Fig. 22 Optical Transmission Spectrum of Corning Filter 4-94

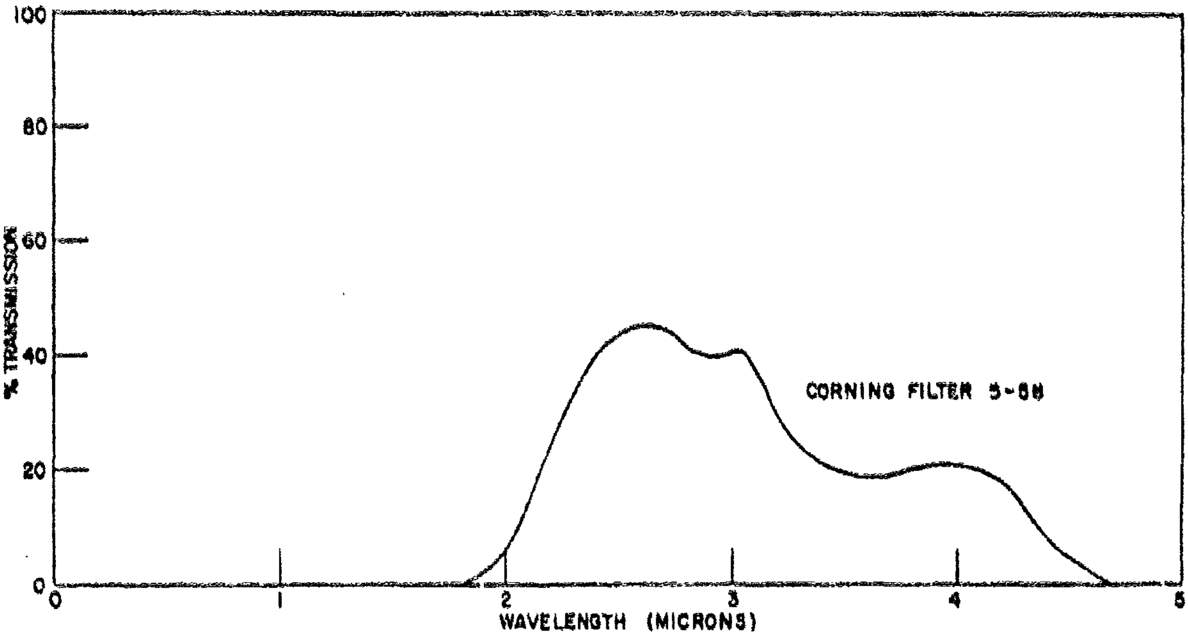


Fig. 23 Optical Transmission Spectrum of Corning Filter 5-58

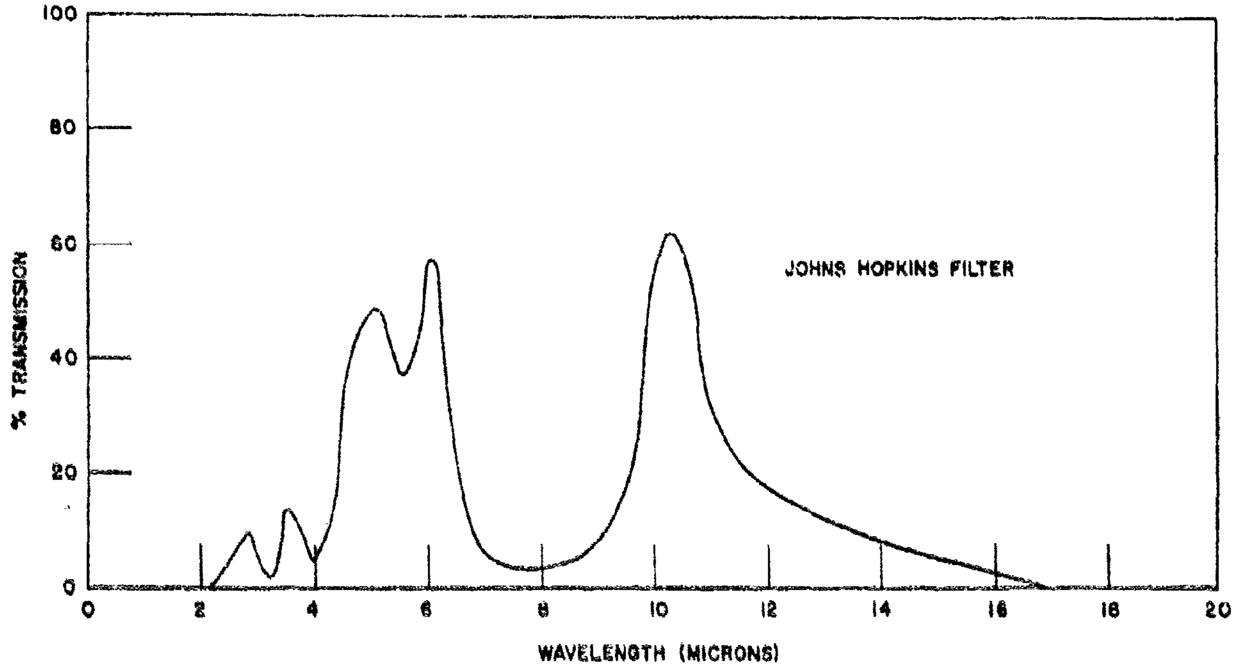


Fig. 24 Optical Transmission Spectrum of Johns Hopkins Filter

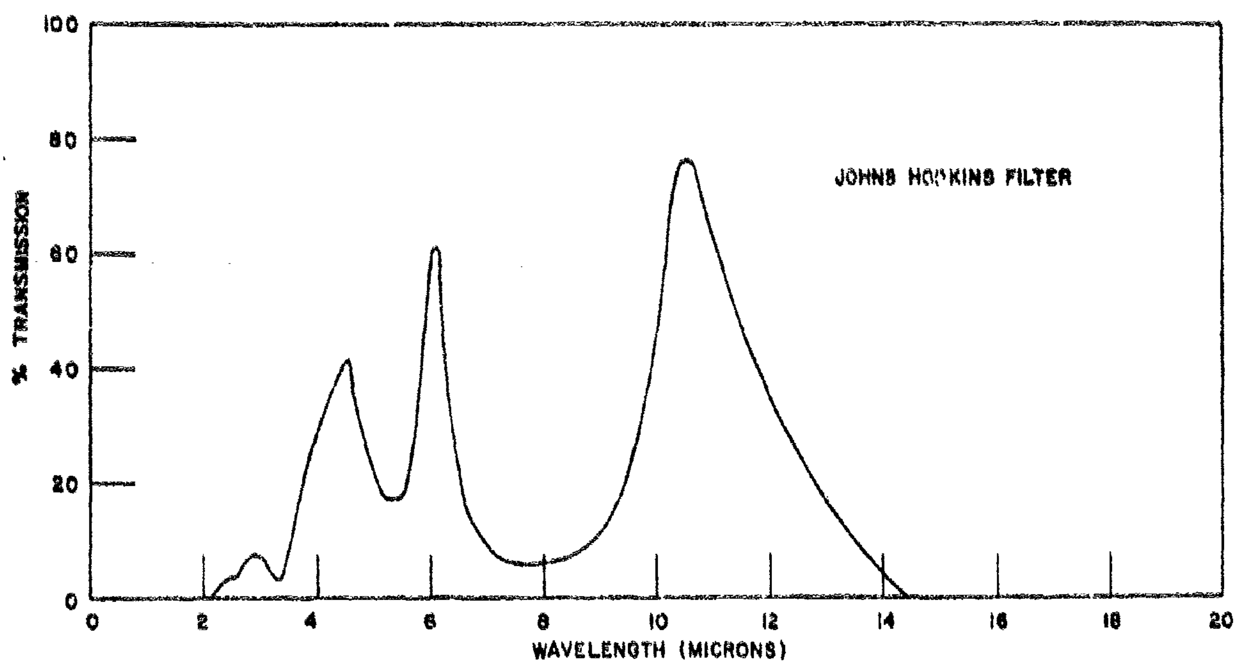


Fig. 25 Optical Transmission Spectrum of Johns Hopkins Filter